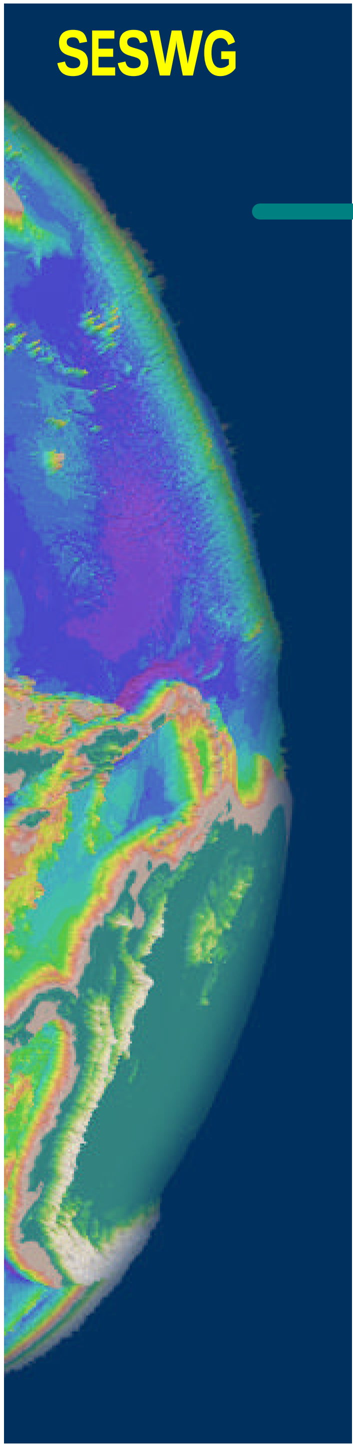


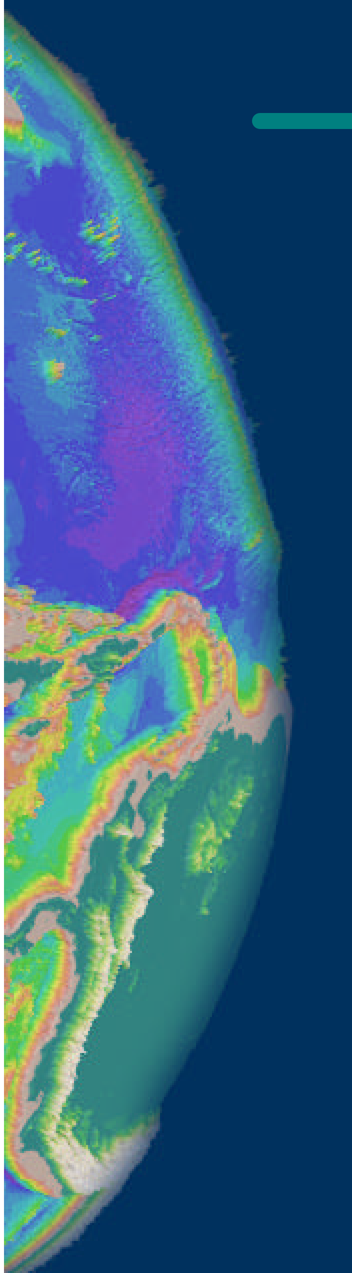
Living on a Restless Planet:

Observing Techniques for Solid Earth Science in the 21st Century

Solid Earth Science Working Group

July 22, 2003

SESWG



The SESWG Charter

- **To guide the science community in the development of a recommended long-term vision and strategy for solid-Earth science at NASA**

Chair: Sean C. Solomon

Victor R. Baker
Jeremy Bloxham
Douglas Burbank
Ben Chao
Alan Chave
Andrea Donnellan
Alan Gillespie
Thomas A. Herring
Raymond Jeanloz
Bernard Minster

Walter C. Pitman, III
Eric Rignot
Mark Simons
Byron Tapley
Donald Turcotte
Mary Lou C. Zoback

John LaBrecque (ex-officio)
Charles Elachi (ex-officio)
Diane Evans (ex-officio)

Web Page: http://solidearth.jpl.nasa.gov

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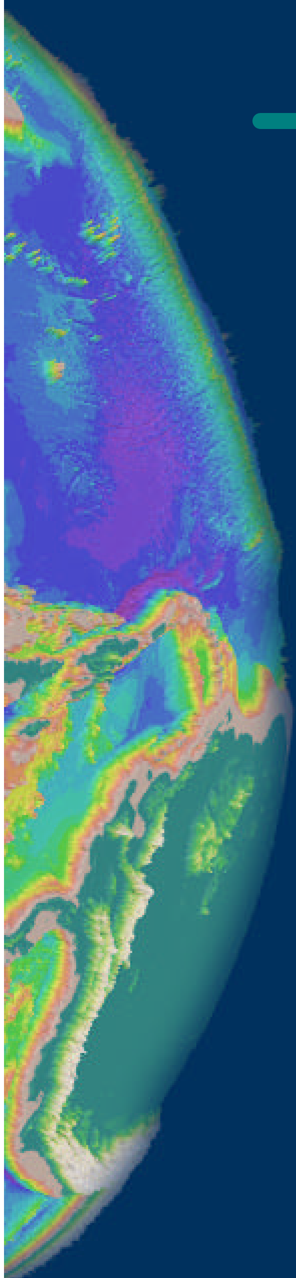


Scientific Imperatives

ESE Goal and Leading Solid Earth Science Questions

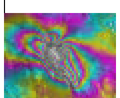
Observe, understand, and model the Earth system to learn how it is changing and the consequences for life on Earth.

How is the Earth's surface being transformed and how can such information be used to predict future changes?

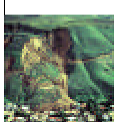
What are the motions of the Earth and the Earth's interior, and what information can be inferred about Earth's internal processes?

Scientific Challenges Identified by the SESWG

1. What is the nature of deformation at plate boundaries and what are the implications for earthquake hazards?

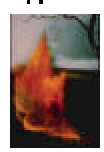


2. How do tectonics and climate interact to shape the Earth's surface and create natural hazards?

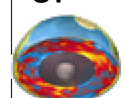


3. What are the interactions among ice masses, oceans, and the solid Earth and their implications for sea level change?

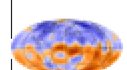
4. How do magmatic systems evolve and under what conditions do volcanoes erupt?



5. What are the dynamics of the mantle and crust and how does the Earth's surface respond?



6. What are the dynamics of the Earth's magnetic field and its interactions with the Earth system?



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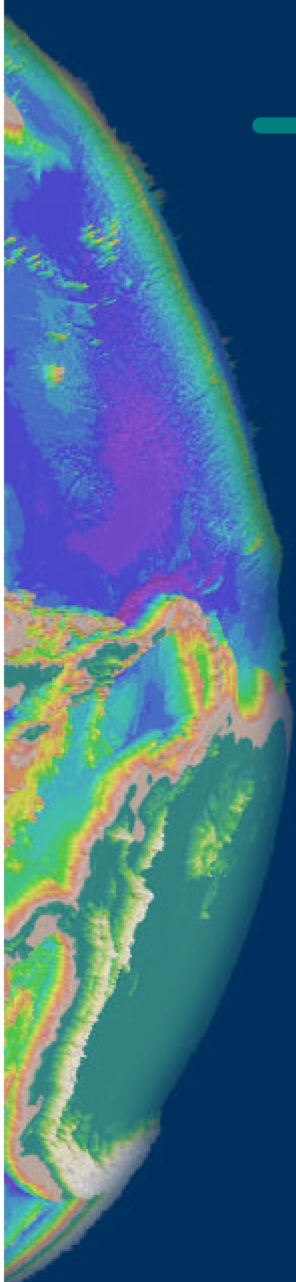
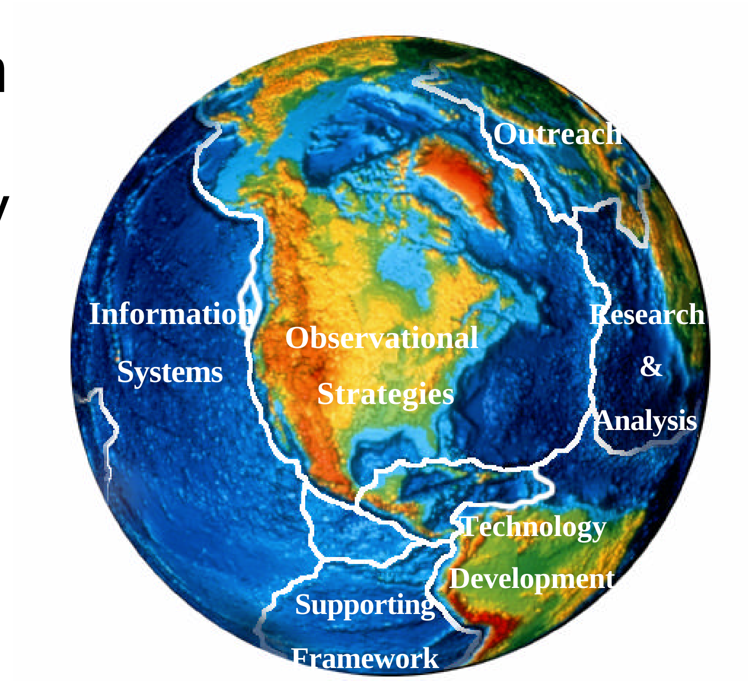


Recommendations for an Integrated Program for Solid-Earth Science

- An integrated solid-Earth program addresses observations, technology development, R&A (including modeling), information systems, supporting frameworks, and outreach.



- By developing a modular program architecture, the overall effort is responsive to scientific discoveries and new programmatic directions.

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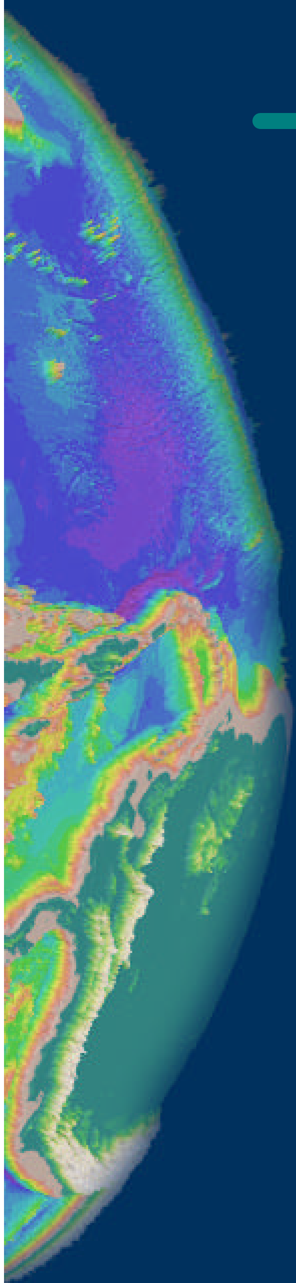

Observational Strategies

- To address the six cross-cutting scientific challenges, a suite of high-priority observational strategies has been identified.
- The motivation for and expected benefits from each observational strategy will be highlighted throughout the presentation.

1. **Surface deformation**
2. **High-resolution topography**
3. **Variability of Earth’s magnetic field**
4. **Variability of Earth’s gravity field**
5. **Imaging spectroscopy of Earth’s changing surface**
6. **Space geodetic networks and the ITRF**
7. **Promising techniques and observations**

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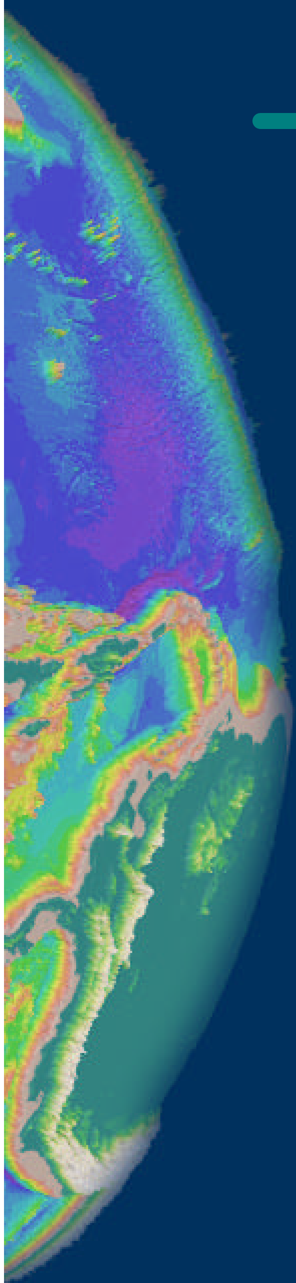
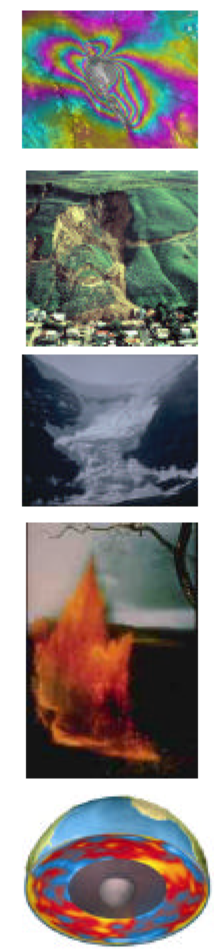
Observations: Surface Deformation



Suggested mission phasing and requirements

- *Immediate (1–5 years)*: Single dedicated InSAR satellite
  - L-band, with left/right-looking capability and weekly access to anywhere on the globe
  - Precise orbit determination and ionospheric correction capabilities
  - 1 mm/yr surface displacement over 50 km horizontal extents; displacement maps should cover 100-km-wide swaths
- *Near Term (5–10 years):* Constellation of InSAR satellites
  - Improved temporal frequency of deformation maps to daily intervals
  - Maps at several hundred km width with full vector surface displacements at accuracies of submillimeter per year over 10-km spatial extents and 1-m spatial resolution
- *Long term (10–25 years)*: Constellation of InSAR satellites in low Earth or geosynchronous orbits
  - Hourly global access
  - Increase density of continuous ground and seafloor geodetic observations

Scientific challenges addressed by these observations



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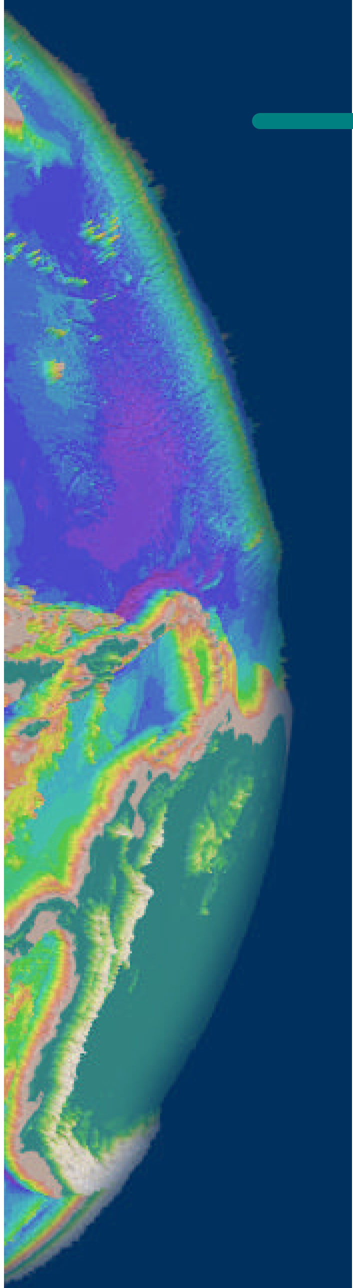
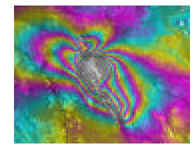


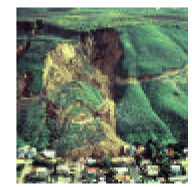
Observations: High-resolution Topography

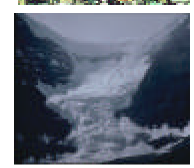
Suggested mission phasing and requirements

- *Immediate (1–5 years)*: Distribute all SRTM data, launch ICESat, and demonstrate imaging lidar capabilities in Earth orbit
- *Near Term (5–10 years):* Global mapping to supercede the SRTM data set
  - One-time, non-repeated global mapping at 2- to 5-m resolution and 0.5-m vertical accuracy for the ground surface
  - Ice-sheet mapping with 1-km horizontal resolution, 1-cm vertical accuracy for the ice or snow surface, and a repeat interval of months (for annual changes) to years (for long-term changes)
- *Long term (10–25 years)*: Continuously operating, targeted, high-resolution topographic mapping and change detection capability
  - Targeted local to regional mapping, with global access, at 1-m resolution, 0.1-m vertical accuracy for the ground and water surfaces, and a repeat frequency of hours to years depending on the rate of topographic change

Scientific challenges addressed by these observations







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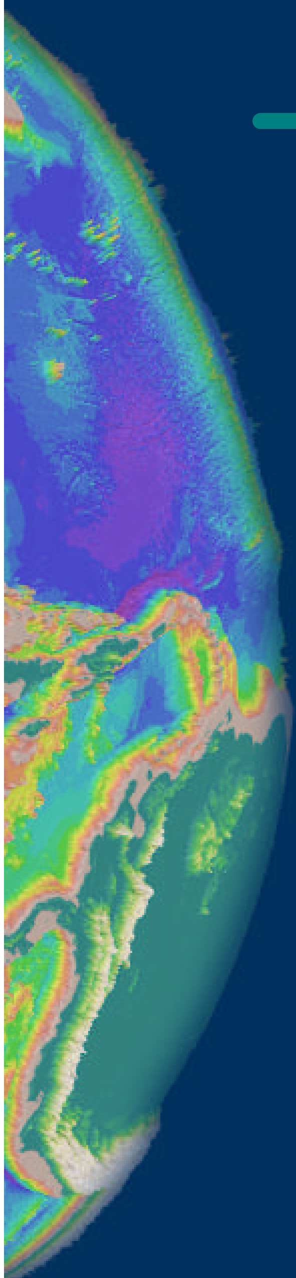
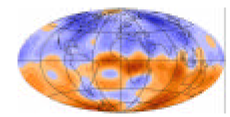


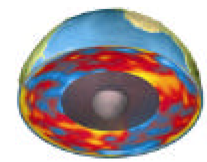
Observations: Geomagnetic Field

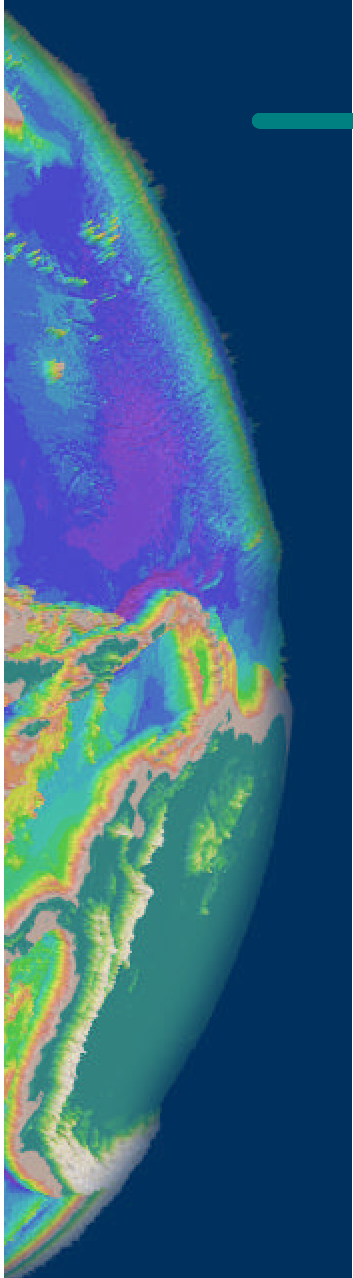
Suggested mission phasing and requirements

- *Immediate (1–5 years)*: Support of analysis of geomagnetic observations from current satellite missions
  - Development of a modularized instrument package to facilitate taking advantage of missions of opportunity
- *Near Term (5–10 years):* Constellation of 4-6 satellites
  - At a range of local times
  - Approximately 800-km altitude in polar orbit
- *Long term (10–25 years)*: Complete, 12-satellite constellation
  - Adding satellites at lower altitude (300 km) in polar orbit (to enhance study of the crustal field)
  - At 800 km in a low-inclination orbit (to enhance recovery of mantle electrical conductivity)
  - Technological advancements on incorporating star trackers on magnetometers and improved lifetimes at low altitudes

Scientific challenges addressed by these observations





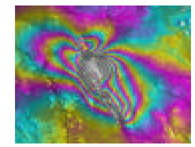


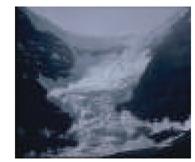
Observations: Gravity Field

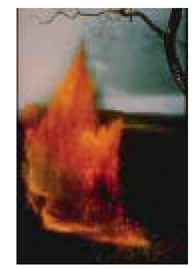
Suggested mission phasing and requirements

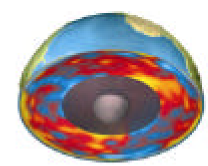
- *Immediate (1–5 years):* GRACE
  - Monthly estimation to within a few millimeters of surface water-equivalent load at a few hundred kilometers spatial resolution
- *Near Term (5–10 years):* GRACE follow-on mission
  - Demonstrating satellite-to-satellite laser interferometry technology
- *Long term (10–25 years):* Gravity measurement improved by 2–3 orders of magnitude in sensitivity
  - Satellite-to-satellite laser interferometry or
  - Spaceborne quantum gradiometer technology

Scientific challenges addressed by these observations









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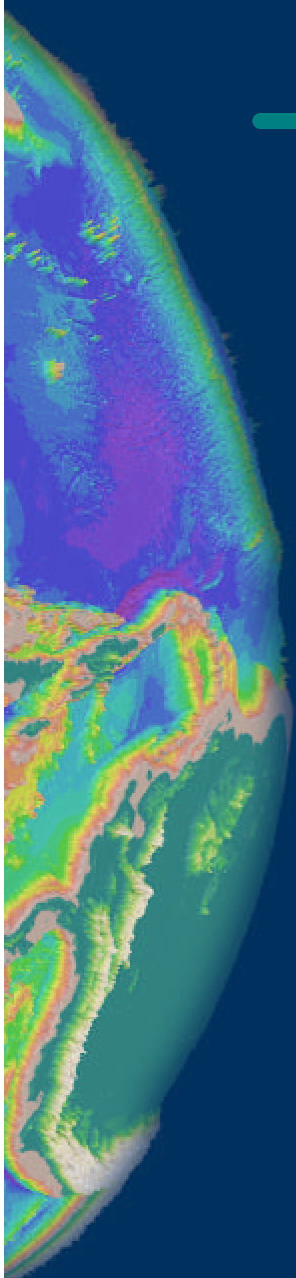
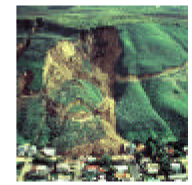


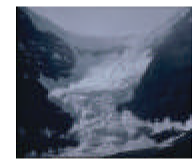
Observations: Imaging Spectroscopy

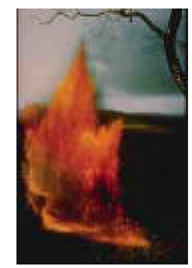
Suggested mission phasing and requirements

- *Immediate (1–5 years):* Spaceborne imaging spectrometer
  – Visible and near infrared (0.2 – 2.5 µm)
  – Airborne measurements in the thermal infrared (3 – 5 µm and 8 – 14 µm)
- *Near Term (5–10 years):* Improved spaceborne imaging spectrometer
  – 100-km swath and 30-m spatial resolution
  – Demonstration spaceborne thermal infrared imaging spectrometer with 30-km swath and 30-m spatial resolution
  – Monthly global mapping across visible to thermal wavelengths with a signal-to-noise ratio > 500
- *Long Term (10–25 years):* Targeted local to regional mapping, with global access, at 1-m resolution across multiple wavelengths
  – Repeat frequency of hours to years depending on the rate of change of the process being studied

Scientific challenges addressed by these observations







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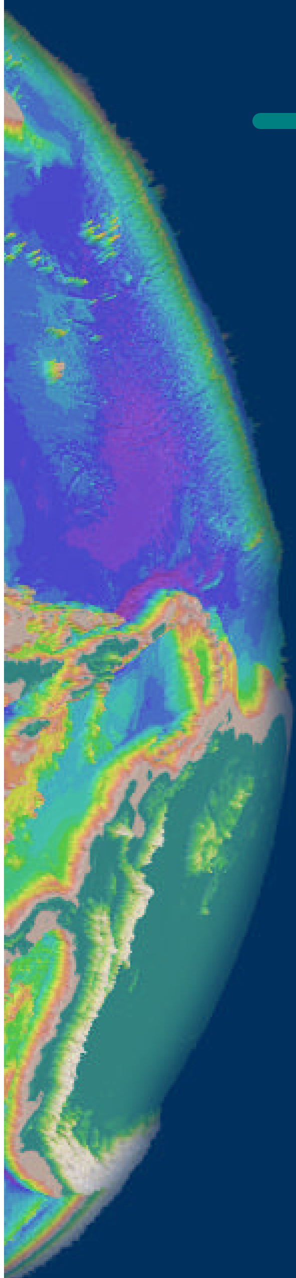
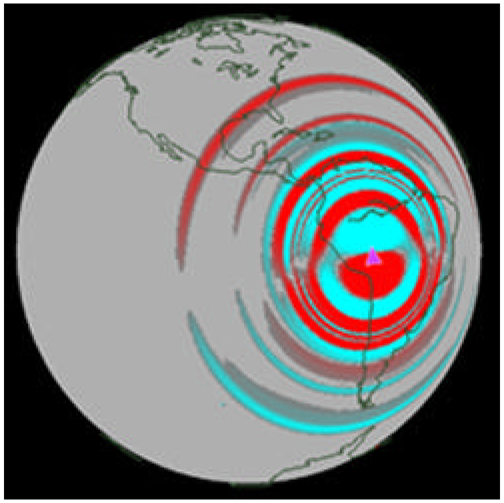


Observations: Promising Directions

- A number of other promising observations that are either developing or expanding into the field of solid-Earth science offer additional methods to achieve the goals of the Solid Earth Science Program.

- Seismology from space
- Subsurface imaging
- Solid Earth beneath the oceans



Propagation of seismic waves from the 1994 magnitude 8.2 Bolivia earthquake. It may be possible to measure seismic waves on continental scales from space.

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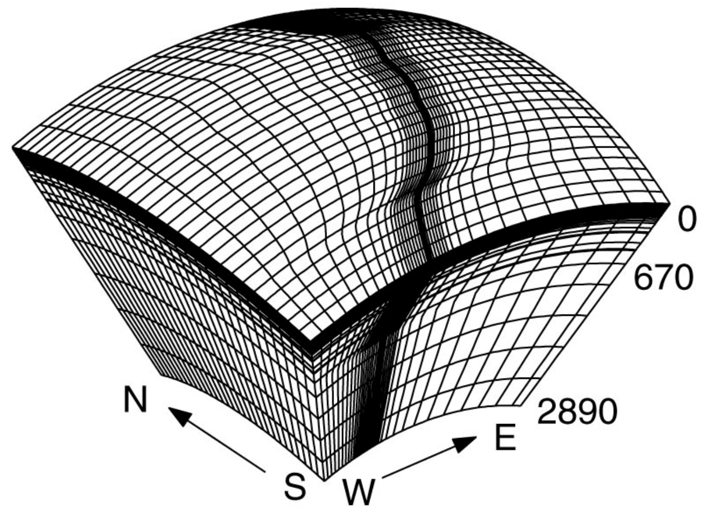
Information Systems

- Computational Priorities
  - Advances in inversion methods, 3D modeling, data assimilation and pattern recognition all require high-performance computing.
- Distributed Receiving and Processing Systems
  - The creation of distributed centers for processing and storing and comparing complementary data sets is important for interdisciplinary research.



Three-dimensional finite element grid for modeling mantle flow and crustal deformation along a subduction zone. Modeling techniques such as this are very computationally intensive.

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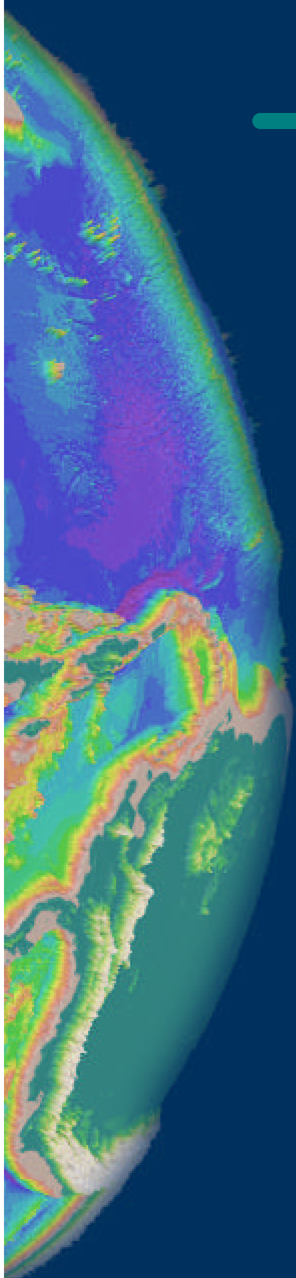
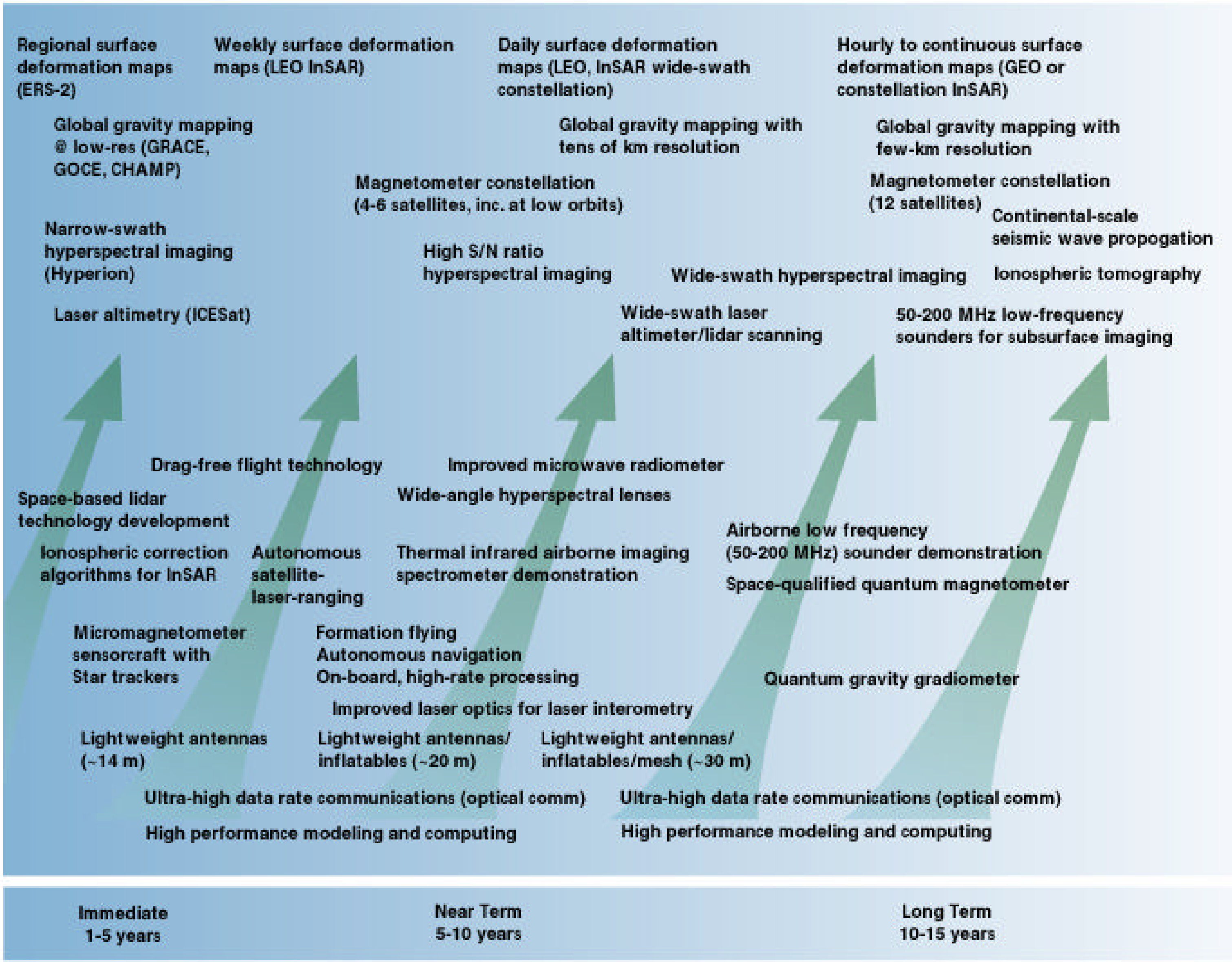
Technology Development





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Toward An Integrated Global Earth Observing System